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Q1. (a) The limiting reactant is the reactant that is completely consumed in a chemical reaction.

(b) The limiting reactant is not always the chemical present in the fewest number of moles. It is the reactant that will form fewer moles of product.

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1. $\text{Fe}(\text{NO}_3)_2(\text{aq})$
2. 1.9 g
3. 22 g
4. 7.7 g
5. The zinc would react completely.
6. $\text{NH}_3(\text{g})$ is the limiting reagent.

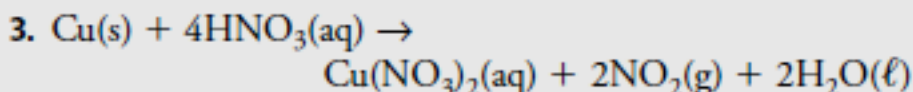
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7. The limiting reagent is $\text{Mg}(\text{NO}_3)_2(\text{aq})$
 8. 4 g
 9. Since $\text{HgCl}_2(\text{aq})$ is the limiting reagent, there is sufficient $\text{Na}_2\text{S}(\text{aq})$ to precipitate all of the $\text{Hg}^{2+}(\text{aq})$ ions from the solution.
 10. 15 g
$$\text{Pb}(\text{NO}_3)_2(\text{aq}) + 2\text{KI}(\text{aq}) \rightarrow \text{PbI}_2(\text{s}) + 2\text{KNO}_3(\text{aq})$$
 11. (a) $\text{CuSO}_4(\text{aq}) + \text{Sr}(\text{NO}_3)_2(\text{aq}) \rightarrow \text{Cu}(\text{NO}_3)_2(\text{aq}) + \text{SrSO}_4(\text{s})$
 - (b) The filtrate will be red.
 - (c) Priti should expect approximately 1.47 g of precipitate.
 - (d) The percentage yield is 97.4%.
 12. (a) $\text{Na}_2\text{SiO}_3(\text{aq}) + 2\text{AgNO}_3(\text{aq}) \rightarrow \text{Ag}_2\text{SiO}_3(\text{s}) + 2\text{NaNO}_3(\text{aq})$
 - (b) Since the concentration and volume of silver nitrate, $\text{AgNO}_3(\text{aq})$, produces less precipitate, it is the limiting reagent.
-
- (c) The predicted yield is 4.9 g $\text{Ag}_2\text{SiO}_3(\text{s})$.
 - (d) Yes, all of the silver ions would be removed from the solution since all of the limiting reagent, which in this case is $\text{AgNO}_3(\text{aq})$, is consumed in the reaction.

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1. You need not consider reactants that are in excess, as they do not determine the yield of the reaction; only the limiting reactant will influence the yield. Student analogies will vary. Most students will provide analogies of recipes.
2. (a) The $\text{O}_2(\text{g})$ will be in excess because the amount of $\text{P}_4(\text{s})$ is set, while the quantity of oxygen in air is virtually limitless.
 (b) Gold is far too expensive to be in excess. Due to its prohibitive cost, a chemist would want to use all the gold in the reaction.
 (c) The characteristics of a reactant that would make it suitable as an excess reactant would be low cost, high solubility (because most reactions take place in water), and ease of disposal (non-toxic).



$$m = 57.4 \text{ g} \quad m = 140 \text{ g} \quad m = ? \text{ g}$$

$$M = 63.55 \text{ g/mol} \quad M = 63.02 \text{ g/mol} \quad M = 187.57 \text{ g/mol}$$

If $\text{Cu}(\text{s})$ is limiting:

$$m_{\text{Cu}(\text{NO}_3)_2} = 57.4 \text{ g Cu} \times \frac{1 \text{ mol Cu}}{63.55 \text{ g Cu}} \times \frac{1 \text{ mol Cu}(\text{NO}_3)_2}{1 \text{ mol Cu}} \times \frac{187.57 \text{ g Cu}(\text{NO}_3)_2}{1 \text{ mol Cu}(\text{NO}_3)_2}$$

$$= 169 \text{ g}$$

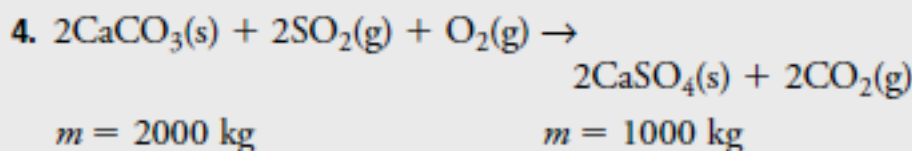
If $\text{HNO}_3(\text{aq})$ is limiting:

$$m_{\text{Cu}(\text{NO}_3)_2} = 140 \text{ g HNO}_3 \times \frac{1 \text{ mol HNO}_3}{63.02 \text{ g HNO}_3} \times \frac{1 \text{ mol Cu}(\text{NO}_3)_2}{4 \text{ mol HNO}_3} \times \frac{187.57 \text{ g Cu}(\text{NO}_3)_2}{1 \text{ mol Cu}(\text{NO}_3)_2}$$

$$= 104 \text{ g}$$

(a) Since the $\text{HNO}_3(\text{aq})$ will produce the least amount of product, it is the limiting reactant. Therefore, the $\text{Cu}(\text{s})$ is the reactant in excess.

(b) The mass of $\text{Cu}(\text{NO}_3)_2(\text{aq})$ that could be obtained is 156 g.



$$M = 100.09 \text{ g/mol}$$

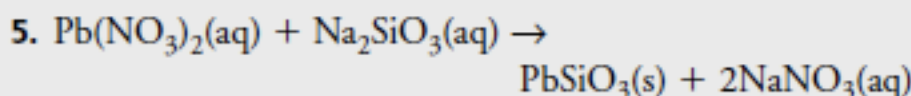
$$M = 64.07 \text{ g/mol}$$

If $\text{CaCO}_3(\text{s})$ is limiting:

$$m\text{SO}_2 = 2000 \text{ kg } \text{CaCO}_3 \times \frac{1 \text{ mol } \text{CaCO}_3}{100.09 \text{ g } \text{CaCO}_3} \times \frac{2 \text{ mol } \text{SO}_2}{2 \text{ mol } \text{CaCO}_3} \times \frac{64.07 \text{ g } \text{SO}_2}{1 \text{ mol } \text{SO}_2}$$

$$= 1280 \text{ kg}$$

According to the previous calculation, the quantity of $\text{SO}_2(\text{g})$ that can be removed is 1280 kg. Since only 1000 kg is present, it will be completely removed.



$$m = 7.16 \text{ g}$$

$$m = 20 \text{ g}$$

$$m = ? \text{ g}$$

$$M = 331.23 \text{ g/mol} \quad M = 122.07 \text{ g/mol} \quad M = 283.30 \text{ g/mol}$$

If $\text{Pb}(\text{NO}_3)_2(\text{aq})$ is limiting:

$$m\text{PbSiO}_3 = 7.16 \text{ g } \text{Pb}(\text{NO}_3)_2 \times \frac{1 \text{ mol } \text{Pb}(\text{NO}_3)_2}{331.23 \text{ g } \text{Pb}(\text{NO}_3)_2} \times \frac{1 \text{ mol } \text{PbSiO}_3}{1 \text{ mol } \text{Pb}(\text{NO}_3)_2} \times \frac{283.30 \text{ g } \text{PbSiO}_3}{1 \text{ mol } \text{PbSiO}_3}$$

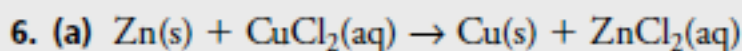
$$= 6.1 \text{ g}$$

If $\text{Na}_2\text{SiO}_3(\text{aq})$ is limiting:

$$m_{\text{PbSiO}_3} = 20 \text{ g } \cancel{\text{Na}_2\text{SiO}_3} \times \frac{1 \text{ mol } \cancel{\text{Na}_2\text{SiO}_3}}{122.07 \text{ g } \cancel{\text{Na}_2\text{SiO}_3}} \times \frac{1 \text{ mol } \text{PbSiO}_3}{1 \text{ mol } \cancel{\text{Na}_2\text{SiO}_3}} \times \frac{283.30 \text{ g } \text{PbSiO}_3}{1 \text{ mol } \text{PbSiO}_3}$$

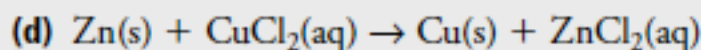
$$= 46 \text{ g}$$

Since the $\text{Pb}(\text{NO}_3)_2$ produces the least amount of product, it is the limiting reactant and the mass of precipitate to be collected will be 6.1 g.



(b) To analyze the reaction, students should record the initial mass of zinc, final mass of zinc, initial colour of the solution, and final colour of the solution.

(c) The presence of the blue colour indicates $\text{Cu}^{2+}(\text{aq})$ ions are left over at the end of the reaction, making $\text{CuCl}_2(\text{aq})$ the reactant in excess.



$$m = ? \text{ g}$$

$$m = 3.12 \text{ g}$$

$$M = 65.39 \text{ g/mol} \quad M = 134.45 \text{ g/mol}$$

$$m_{\text{Zn}} = 3.12 \text{ g } \cancel{\text{CuCl}_2} \times \frac{1 \text{ mol } \cancel{\text{CuCl}_2}}{134.45 \text{ g } \cancel{\text{CuCl}_2}} \times \frac{1 \text{ mol } \text{Zn}}{1 \text{ mol } \cancel{\text{CuCl}_2}} \times \frac{65.39 \text{ g } \text{Zn}}{1 \text{ mol } \text{Zn}}$$

$$= 1.52 \text{ g}$$

The stoichiometric amount of $\text{Zn}(\text{s})$ required to react with the $\text{CuCl}_2(\text{aq})$ was 1.52 g. Since some $\text{CuCl}_2(\text{aq})$

remained at the end of the reaction, the mass of zinc powder added must have been less than 1.52 g.

7. (a) Yes, all of the sulfuric acid was neutralized.
(b) 0.346 g of sodium hydrogen carbonate remained.
(c) 87 mL of carbon dioxide was produced.
(d) If sodium hydroxide was used to neutralize sulfuric acid, any excess sodium hydroxide would make the spill basic. When sodium hydrogen carbonate is used, the by-products are a neutral salt (sodium sulfate), carbon dioxide, and water. No acid or base remains.
8. Wear gloves, goggles, and an apron. Add a minimum of 266 mL of a 1.00 mol/L solution of sodium chloride to the silver nitrate. (For the sake of safety, it would be wise to use 300 mL of sodium chloride.) The silver ions will precipitate out in the form of silver chloride. Filter the solution using a funnel lined with filter paper situated in an Erlenmeyer flask. Dispose of the filter paper with the precipitate in a solid waste container or dry it and place the silver chloride in a labelled container. A total of about 29 g of silver in the form of silver chloride will be recovered from the solution.

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- Q2. (a) The following five factors can limit or reduce the yield of a chemical reaction: a competing reaction, collection and transfer methods, reactant purity, a reaction that does not proceed to completion, and a slow reaction.

- (b) The predicted yield is higher than the experimental yield for a reaction, because predicted yield is the maximum quantity of product expected from a reaction and is rarely met.

Q3. 64%

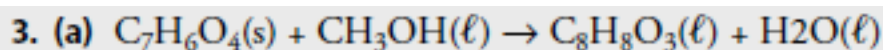
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- 13. (a)** 11.4 g Cu(s)
(b) 79% yield
- 14.** 60% yield
- 15.** Trial 1: 95.5%, Trial 2: 94.3%, and Trial 3: 97.2%
Average is 95.7%.
- 16.** 95.2% yield
- 17.** 26.7% yield
- 18. (a)** 2.88 g
(b) 97.3% yield
- 19. (a)** 15.0 g
(b) 10.5 g
(c) 12.8 g

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1. The units used when calculating a percentage yield of a product would have no effect on the calculation, as they will cancel in the equation.
2. If the limiting reactant is impure, the percentage yield of the reaction would decrease, because the amount of limiting reagent would be less than what was used in the prediction.



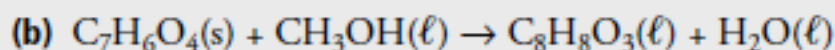
$$m = 3.50 \text{ g}$$

$$m = ?$$

$$M = 138.13$$

$$M = 152.16$$

$$\begin{aligned} m(\text{C}_8\text{H}_8\text{O}_3) &= 3.50 \text{ g } \cancel{\text{C}_7\text{H}_6\text{O}_4} \times \frac{1 \text{ mol } \cancel{\text{C}_7\text{H}_6\text{O}_4}}{138.13 \text{ g } \cancel{\text{C}_7\text{H}_6\text{O}_4}} \\ &\quad \times \frac{1 \text{ mol } \cancel{\text{C}_8\text{H}_8\text{O}_3}}{1 \text{ mol } \cancel{\text{C}_7\text{H}_6\text{O}_4}} \times \frac{152.16 \text{ g } \text{C}_8\text{H}_8\text{O}_3}{1 \text{ mol } \cancel{\text{C}_8\text{H}_8\text{O}_3}} \\ &= 3.86 \text{ g} \end{aligned}$$



$$m = 3.50 \text{ g} - 2.84 \text{ g}$$

$$m = 0.66 \text{ g}$$

$$m = ?$$

$$M = 138.13$$

$$M = 152.16$$

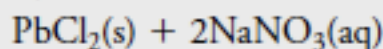
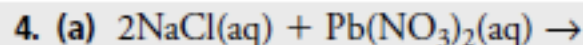
$$\begin{aligned} m(\text{C}_8\text{H}_8\text{O}_3) &= 0.66 \text{ g } \cancel{\text{C}_7\text{H}_6\text{O}_4} \times \frac{1 \text{ mol } \cancel{\text{C}_7\text{H}_6\text{O}_4}}{138.13 \text{ g } \cancel{\text{C}_7\text{H}_6\text{O}_4}} \\ &\quad \times \frac{1 \text{ mol } \cancel{\text{C}_8\text{H}_8\text{O}_3}}{1 \text{ mol } \cancel{\text{C}_7\text{H}_6\text{O}_4}} \times \frac{152.16 \text{ g } \text{C}_8\text{H}_8\text{O}_3}{1 \text{ mol } \cancel{\text{C}_8\text{H}_8\text{O}_3}} \\ &= 0.727 \text{ g} \end{aligned}$$

(c) Percentage Yield = $\frac{\text{Experimental Yield}}{\text{Predicted Yield}} \times 100\%$

$$= \frac{0.7270 \text{ g}}{3.8555 \text{ g}} \times 100 \%$$

$$= 18.886\%$$

$$\cong 18.9\%$$



$$m = 0.58 \text{ g}$$

$$m = 3.50 \text{ g}$$

$$m = ? \text{ g}$$

$$M = 58.44 \text{ g/mol} \quad M = 331.23 \text{ g/mol} \quad M = 278.11 \text{ g/mol}$$

If NaCl is limiting:

$$m\text{PbCl}_2 = 0.58 \text{ g NaCl} \times \frac{1 \text{ mol NaCl}}{58.44 \text{ g NaCl}} \times \frac{1 \text{ mol PbCl}_2}{2 \text{ mol NaCl}} \times \frac{278.11 \text{ g PbCl}_2}{1 \text{ mol PbCl}_2} \\ = 1.4 \text{ g}$$

If Pb(NO₃)₂ is limiting:

$$m\text{PbCl}_2 = 3.50 \text{ g Pb(NO}_3)_2 \times \frac{1 \text{ mol Pb(NO}_3)_2}{331.23 \text{ g Pb(NO}_3)_2} \times \frac{1 \text{ mol PbCl}_2}{1 \text{ mol Pb(NO}_3)_2} \times \frac{278.11 \text{ g PbCl}_2}{1 \text{ mol PbCl}_2} \\ = 2.94 \text{ g}$$

Since the NaCl(aq) produces the least amount of product, it is the limiting reactant and the mass of precipitate to be collected will be 1.4 g.

$$\text{(b) Percentage Yield} = \frac{\text{Experimental Yield}}{\text{Predicted Yield}} \times 100 = \\ \frac{1.22 \text{ g}}{1.38 \text{ g}} \times 100 = 88\%$$

The percentage yield is 87%.



$$m = 100 \text{ g} \quad m = 54 \text{ g} \quad m = ? \text{ g}$$

$$M = 152.00 \text{ g/mol} \quad M = 26.98 \text{ g/mol} \quad M = 52.00 \text{ g/mol}$$

If Cr₂O₃ is limiting:

$$m\text{Cr} = 100 \text{ g Cr}_2\text{O}_3 \times \frac{1 \text{ mol Cr}_2\text{O}_3}{152.00 \text{ g Cr}_2\text{O}_3} \times \frac{2 \text{ mol Cr}}{1 \text{ mol Cr}_2\text{O}_3} \times \frac{52.00 \text{ g Cr}}{1 \text{ mol Cr}} \\ = 68 \text{ g}$$

If Al is limiting:

$$m_{\text{Cr}} = 54 \text{ g Al} \times \frac{1 \text{ mol Al}}{26.98 \text{ g Al}} \times \frac{1 \text{ mol Cr}}{1 \text{ mol Al}} \times \frac{52.00 \text{ g Cr}}{1 \text{ mol Cr}} \\ = 104 \text{ g}$$

Since the $\text{Cr}_2\text{O}_3(\text{s})$ produces the least amount of product, it is the limiting reactant and the mass of precipitate to be collected will be 68 g.

$$\begin{aligned} \text{(b) Percentage Yield} &= \frac{\text{Experimental Yield}}{\text{Predicted Yield}} \times 100 \\ &= \frac{60 \text{ g}}{68.4 \text{ g}} \times 100 = 88\% \end{aligned}$$

The percentage yield is 88%.

6. The design should include dissolving a known mass of silver nitrate in water and reacting it with excess copper

metal. The reaction should be allowed to go to completion, and the silver metal should be recovered by filtration. The predicted yield of product can be calculated stoichiometrically from the mass of the silver nitrate. The percentage yield can be calculated using the mass of silver metal collected in the experiment and the predicted yield.

7. Using cool solvent removes traces of reactants or other products from the precipitate during rinsing. Some of the precipitate will also dissolve in the solvent, but this is limited.
8. It is important for chemists to know the purity of their reactants because impurities can result in reduced yields.

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- Q4.** The titrant is found in the burette. In this example the titrant is HCl(aq) .
- Q5. (a)** Standardization is using a standard solution (a solution with a precisely known concentration) to determine the concentration of another solution by titration.
- (b)** Strong acids need to be standardized because over time the acid concentrations changes.
- (c)** Strong bases need to be standardized as the concentration changes over time, because they tend to absorb carbon dioxide from the air.
- Q6.** In a titration, an indicator is added which has an endpoint (i.e., changes colour) very close to the equivalence point of the reaction. The purpose of an indicator is to provide a visual cue that equivalence point has been reached.
- Q7. (a)** 1.5 mol of HCl(aq) are required to neutralize 1.5 mol of KOH(aq) since the mole ratio of $\text{HCl(aq)} : \text{KOH(aq)}$ is 1:1. The equivalence point occurs when an equal amount (in mol) of HCl(aq) has been added to KOH(aq) .
- (b)** 0.8 mL KOH(aq)

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20. 1 mol/L

21. 0.210 mol/L

22. 0.19 mol/L

23. 0.26 mol/L KOH(aq)

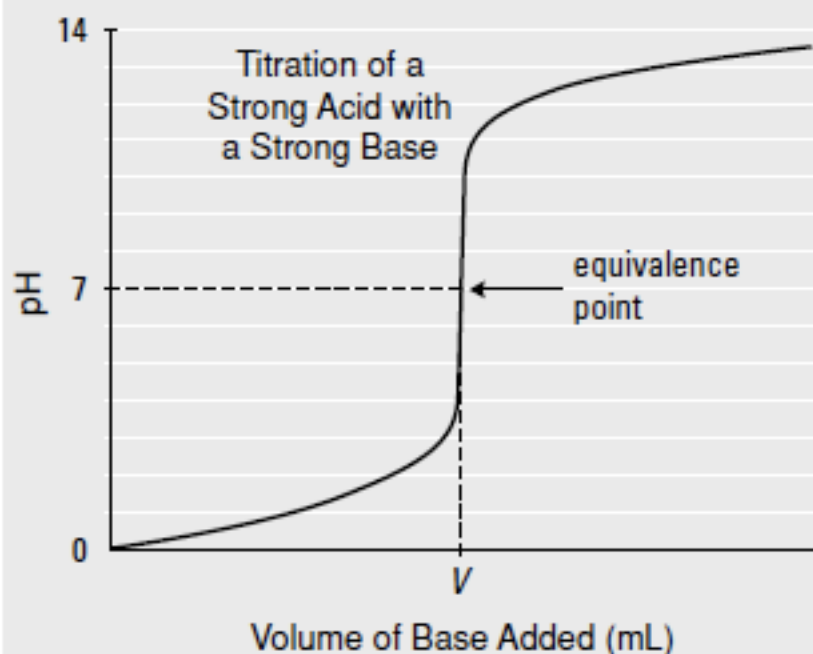
24. (a) 3×10^1 mL

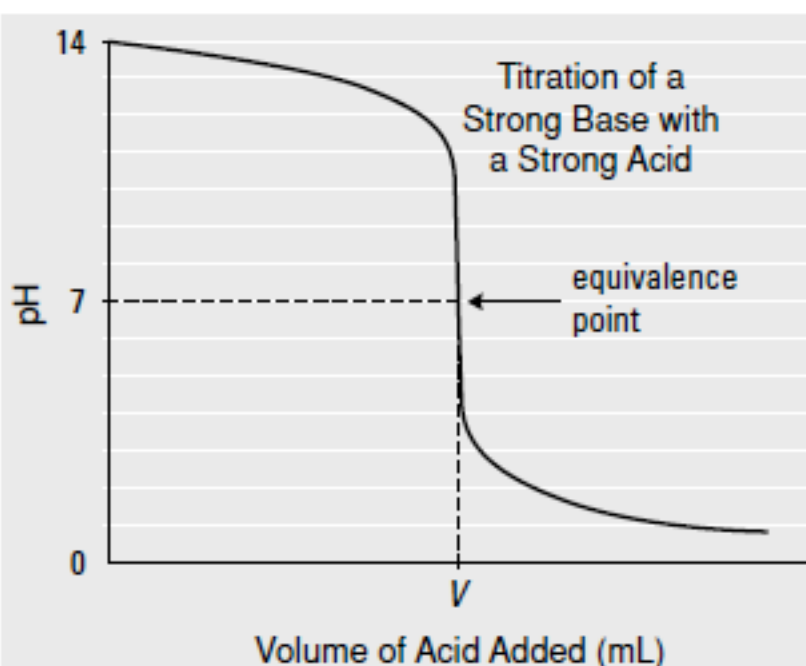
(b) By performing this calculation before the titration, you know approximately the volume of titrant that will be used. The NaOH(aq) can be added quickly up to a few mL of the endpoint, then proceed to titrate slowly towards the endpoint. Therefore, time is saved in performing the titration.

25. 0.524 mol/L

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Q8. A titration curve in which the acid is the titrant would start at a very high pH (the sample is a base). The curve would slope sharply downwards near the equivalence point and then flatten out at a low pH. A titration curve in which the base is the titrant would start at a very low pH (the sample is an acid). The curve would slope sharply upwards near the equivalence point and then flatten out at a high pH.





- Q9.** The equivalence point of the reaction on an acid-base titration curve for a strong acid and a strong base will always occur at pH 7. It appears at the midpoint of the vertical portion of the titration curve.
- Q10.** The steep slope indicates that it takes very little titrant to make a drastic change in the pH of the solution at the equivalence point.

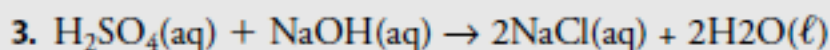
Section 8.3 Review Answers

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1. (a) $\text{KOH(aq)} + \text{HClO}_3\text{(aq)} \rightarrow \text{KClO}_3\text{(aq)} + \text{H}_2\text{O}(\ell)$
- (b) $\text{HI(aq)} + \text{NaOH(aq)} \rightarrow \text{NaI(aq)} + \text{H}_2\text{O}(\ell)$
- (c) $\text{HBr(aq)} + \text{RbOH(aq)} \rightarrow \text{RbBr(aq)} + \text{H}_2\text{O}(\ell)$
- (d) $\text{NaOH(aq)} + \text{HNO}_3\text{(aq)} \rightarrow \text{NaNO}_3\text{(aq)} + \text{H}_2\text{O}(\ell)$
- (e) $2\text{HCl(aq)} + \text{Na}_2\text{CO}_3\text{(aq)} \rightarrow$
 $2\text{NaCl(aq)} + \text{H}_2\text{O}(\ell) + \text{CO}_2\text{(g)}$

2. (a) The endpoint is the pH at which an indicator changes colour. The equivalence point is the pH at which stoichiometrically equivalent amounts of reactants combine. A suitable endpoint occurs with the addition of one drop of extra titrant beyond the equivalence point.

(b) The endpoint pH range and the equivalence point pH need not be identical, but they ought to be very close. The pH changes dramatically at equivalence, so a close endpoint pH range will suffice.



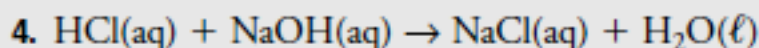
$$V = 23.00 \text{ mL} - 1.05 \text{ mL} \quad V = 10.00 \text{ mL}$$

$$= 21.95 \text{ mL}$$

$$c = 0.118 \frac{\text{mol}}{\text{L}} \quad c = ? \text{ mol/L}$$

$$c \text{ NaOH} = 21.95 \text{ mL} \times \frac{0.118 \text{ mol H}_2\text{SO}_4}{1 \text{ L}} \times \frac{2 \text{ mol NaOH}}{1 \text{ mol H}_2\text{SO}_4} \times \frac{1}{10.00 \text{ mL}}$$

$$= 0.518 \text{ mol/L}$$



Discard trial #1.

$$V_{\text{ave}(\text{NaOH})} = \frac{22.00 \text{ mL} + 22.02 \text{ mL} + 22.04 \text{ mL}}{3}$$

$$= 22.02 \text{ mL}$$

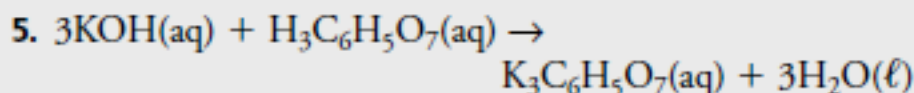
$$V = 10.00 \text{ mL}$$

$$V = 22.02 \text{ mL}$$

$$c = ? \quad c = 0.06649 \frac{\text{mol}}{\text{L}}$$

$$c \text{ HCl} = 22.02 \text{ mL} \times \frac{0.06649 \text{ mol NaOH}}{1 \text{ L}} \times \frac{1 \text{ mol HCl}}{1 \text{ mol NaOH}} \times \frac{1}{10.00 \text{ mL}}$$

$$= 0.1464 \text{ mol/L}$$



$$V = 18.2 \text{ mL} \quad V = 10.00 \text{ mL}$$

$$c = 0.100 \text{ mol/L} \quad c = ? \text{ mol/L}$$

$$\begin{aligned} c \text{ H}_3\text{C}_6\text{H}_5\text{O}_7 &= 18.2 \text{ mL} \times \frac{0.100 \text{ mol KOH}}{1 \text{ L}} \times \\ &\quad \frac{1 \text{ mol H}_3\text{C}_6\text{H}_5\text{O}_7}{3 \text{ mol KOH}} \times \frac{1}{10.00 \text{ mL}} \\ &= 0.0607 \text{ mol/L} \end{aligned}$$

6. (a) This mistake would dilute the acid, requiring a lower volume of titrant and yielding a lower calculated $[\text{HCl}(\text{aq})]$.
- (b) A wet Erlenmeyer flask would have no effect. It is the amount of reactant in the pipetted sample that matters, not its concentration in the Erlenmeyer flask.
- (c) This mistake would create the impression that a greater volume of titrant was necessary, and yield a higher calculated $[\text{HCl}(\text{aq})]$ —the tip of most analytical burettes holds about 1 mL of titrant. This mistake could have contributed to the discrepancy in the problem.
- (d) This would create the false impression that lower volume of titrant was necessary and yield a lower calculated $[\text{HCl}(\text{aq})]$. That said, the effect would be so small as to be within the limits of human error—one drop of titrant is about 0.05 mL.

Chapter 8 Review Answers

Student Textbook pages 324-325

Answers to Understanding Concepts Questions

1. A limiting reactant is a reactant that is completely consumed in a chemical reaction.
2. When reactants are present in stoichiometric amounts they are present in amounts that correspond exactly to the mole ratios.
3. A company may choose to use a large excess of one reactant instead of using stoichiometric amounts of all reactants to ensure that the more expensive or scarcer reactant is consumed and not wasted.
4. The yield of a chemical reaction can be lower than the predicted amount if there is a competing reaction, if the reaction is slow, or the reactant are impure.
5. A certain percentage of the desired compound is lost in every step of an industrial process. A greater percentage is lost as the number of steps increases. For example, it would seem that a recovery of 90% would be good. However, if you recover 90% of the products in every step of a four step process, the final percentage recovered would be:
$$0.90 \times 0.90 \times 0.90 \times 0.90 = 0.66 \text{ or } 66\%.$$
6. The equivalence point is reached first in an acid-base titration. The indicator will just begin to change colour at the equivalence point. The end-point comes when the indicator has completely changed colour or after the pH has completed its change. The equivalence point is at the

mid point of the change in pH when there is exactly the same amount of acid and base present in the solution.

(b) The Erlenmeyer flask may be wet without affecting the data as no volumes are measured in the Erlenmeyer flask and water has no effect on the neutralization reaction taking place.

7. The solution placed in the burette is called the titrant.

Answers to Applying Concepts Questions

8. The student's calculated acid concentration would be higher than the acid's true concentration. The indicator changes outside the steep rise of the curve and well past the equivalence point. As a result, the student would add more base than is actually necessary to neutralize the acid.

9. (a) If the burette is wet, this will dilute the titrant and it will appear as if a greater amount of titrant is required to react with the sample. This will increase the calculated concentration of the sample. If the pipette is wet, this will dilute the sample and a smaller amount of titrant will be required to react with the sample. This will decrease the calculated concentration of the sample.

(b) A wet Erlenmeyer flask would have no effect. It is the amount of reactant in the pipetted sample that matters, not its concentration in the Erlenmeyer flask.

10. (a) i. very low (around pH 1 to 2)
ii. very high (around pH 12 to 13)

(b) i. the same volume as the sample
ii. the same volume as the sample

(c) i. pH 7
ii. pH 7

(d) i. phenolphthalein (or bromothymol blue)
ii. methyl orange (or bromothymol blue)

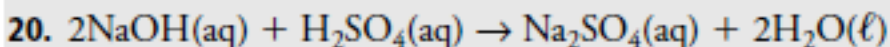
- (e) i. very high (around pH 11 to 12)
- ii. very low (around pH 2 to 3)

Answers to Solving Problems Questions

11. (a) $\text{Zn(s)} + \text{CuCl}_2\text{(aq)} \rightarrow \text{ZnCl}_2\text{(aq)} + \text{Cu(s)}$
- (b) The chemist might look for a precipitate or a colour change.
 - (c) The limiting reactant was zinc.
 - (d) About 1.5 g of zinc was added.
12. (a) The limiting reactant was carbon.
- (b) 23 g of calcium silicate
13. (a) The limiting reactant was oxygen.
- (b) 2.58 g of carbon dioxide were produced.
 - (c) 284 g of excess pentane remained
14. (a) 32.7 g of zinc were produced
- (b) ZnO was the limiting reactant.
 - (c) 14.0 g of carbon monoxide remained after the reaction was complete.
15. (a) The maximum amount of oxygen that could be produced was 0.220 mol or 7.04 g.
- (b) The percentage yield was 93%.
 - (c) 34.4g of nitrogen was formed.
16. (a) The maximum amount of carbon dioxide that could be produced was 52.5 mol or 2.31×10^3 g.
- (b) 1.76×10^3 g of carbon dioxide would be predicted.
17. (a) $\text{NH}_3\text{(g)} + \text{HNO}_3\text{(aq)} \rightarrow \text{NH}_4\text{NO}_3\text{(aq)}$
- (b) The predicted yield of ammonium nitrate would be 80 t.
 - (c) The percentage yield was 79%.

18. The concentration of the sodium hydroxide solution was 0.020 mol/L

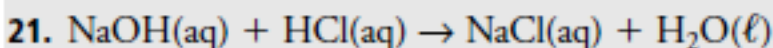
19. The concentration of the nitric acid solution was 0.0842 mol/L.



$$V = 18.0 \text{ mL} \quad V = 15.0 \text{ mL}$$

$$c = 0.500 \text{ mol/L} \quad c = ? \text{ L}$$

$$\begin{aligned} c \text{H}_2\text{SO}_4 &= 18.0 \text{ mL} \times \frac{0.500 \text{ mol NaOH}}{1 \text{ L}} \times \\ &\quad \frac{1 \text{ mol H}_2\text{SO}_4}{2 \text{ mol NaOH}} \times \frac{1}{15.0 \text{ mL}} \\ &= 0.300 \text{ mol/L} \end{aligned}$$



$$V = 25.00 \text{ mL}$$

$$V = 30.21 \text{ mL}$$

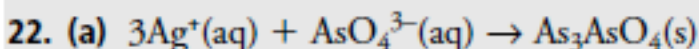
$$c = ? \text{ mol/L}$$

$$c = 1.986 \text{ mol/L}$$

$$\begin{aligned} \text{(a)} \quad c \text{NaOH} &= 30.21 \text{ mL} \times \frac{1.986 \text{ mol HCl}}{1 \text{ L}} \times \\ &\quad \frac{1 \text{ mol NaOH}}{1 \text{ mol HCl}} \times \frac{1}{25.00 \text{ mL}} \\ &= 2.40 \text{ mol/L} \end{aligned}$$

(b) A molar concentration of 2.40 mol/L corresponds to a concentration of 9.60 g/100 mL. This solution is below the acceptable level and therefore cannot be reused.

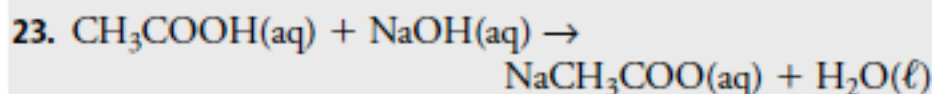
(c) Workers should wear safety glasses, rubber aprons, and gloves as this solution is very corrosive.



(b) $V = 25.0 \text{ mL} \quad m = ? \text{ g}$

$$c = 0.102 \text{ mol/L} \quad M = 138.92 \text{ g/mol}$$

$$\begin{aligned}
 m \text{AsO}_4^{3-} &= 25.0 \text{ mL} \times \frac{0.102 \text{ mol Ag}^+}{1 \text{ L}} \times \\
 &\quad \frac{1 \text{ mol AsO}_4^{3-}}{3 \text{ mol Ag}^+} \times \frac{138.92 \text{ g AsO}_4^{3-}}{1 \text{ mol AsO}_4^{3-}} \\
 &= 118 \text{ mg} \\
 \text{(c) } m \text{As} &= 118 \text{ mg AsO}_4^{3-} \times \frac{74.92 \text{ g As}}{138.92 \text{ g AsO}_4^{3-}} \\
 &= 63.6 \text{ mg As} \\
 \% \text{As} &= \frac{0.0636 \text{ g}}{1.22 \text{ g}} \times 100 = 5.21\%
 \end{aligned}$$



$$\begin{array}{ll}
 V = 2.50 \text{ mL} & V = 34.9 \text{ mL} \\
 c = ? \text{ L} & c = 0.0960 \text{ mol/L}
 \end{array}$$

$$\begin{aligned}
 c \text{CH}_3\text{COOH} &= 34.9 \text{ mL} \times \frac{0.0960 \text{ mol NaOH}}{1 \text{ L}} \times \\
 &\quad \frac{1 \text{ mol CH}_3\text{COOH}}{1 \text{ mol NaOH}} \times \frac{1}{2.50 \text{ mL}} \\
 &= 1.34 \text{ mol/L} \\
 m \text{CH}_3\text{COOH} &= 2.00 \text{ L} \times \frac{1.34 \text{ mol CH}_3\text{COOH}}{1 \text{ L}} \times \\
 &\quad \frac{60.06 \text{ g CH}_3\text{COOH}}{1 \text{ mol CH}_3\text{COOH}} \\
 &= 161 \text{ g}
 \end{aligned}$$

Answers to Making Connections Questions

24. (a) The phosphate-contaminated water could be treated with a solution containing calcium or magnesium ions. (These ions were chosen as they are normally present in hard water.) The precipitate could be removed by settling and then disposed of appropriately.
- (b) Suggested methods may include using detergents or cleaners that do not contain phosphate, replacing phosphate in cleaners with other ions, or treating the water with a biological agent to remove the phosphate (such as a bacterium).